CSCE 585 Project
Milestone P2
Intelligent In-Network Attack Detection

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Problem and motivation

Cyberattacks are evolving, and more intelligent approaches are needed

- Traditional defenses alone are no longer sufficient, requiring adaptive and AI-driven security solutions.

Network speed is increasing, raising the need for in-network acceleration

- As data volumes grow, systems must process and respond in real time to keep pace with modern demands.

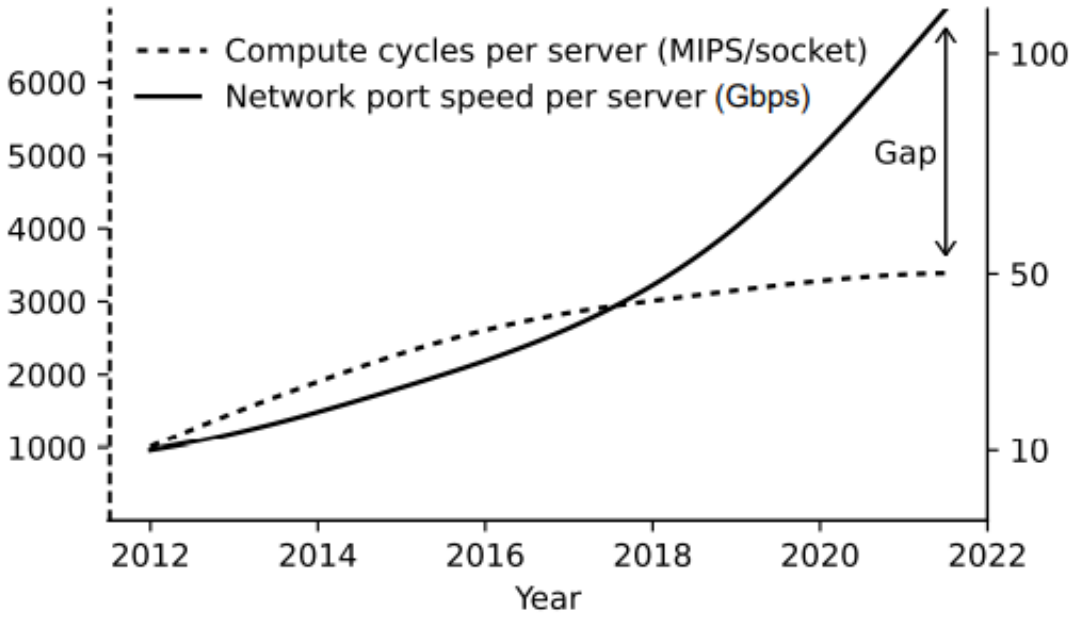


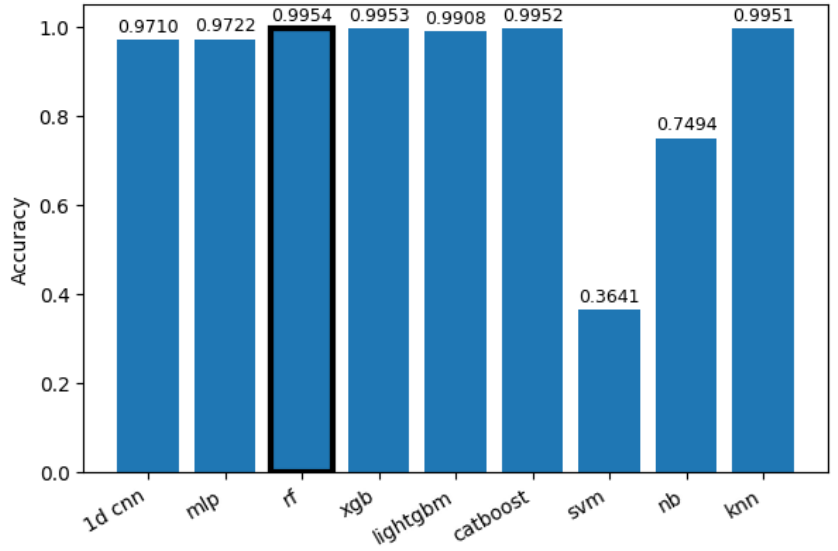
Figure: G. Elinoff, “Data centers are overloaded. The inventor of FPGAs is swooping in with a “comprehensive” SmartNIC,” March 2020.

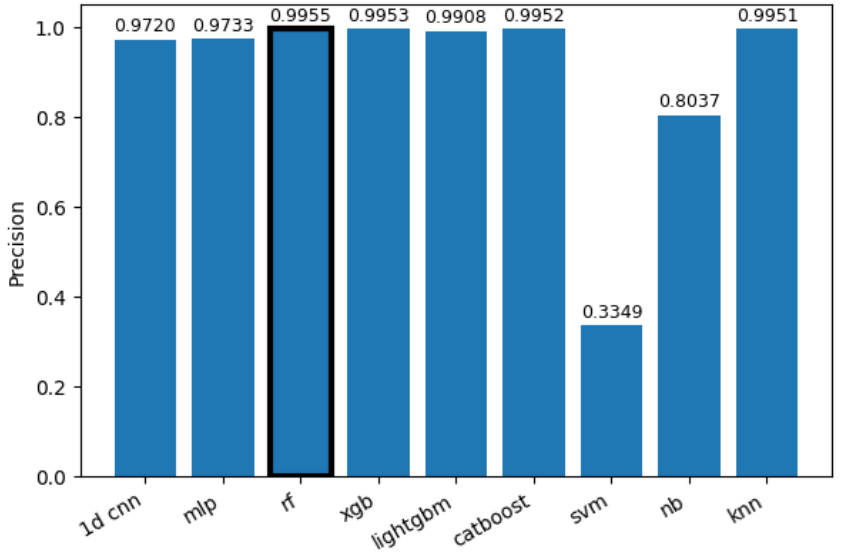
Methods

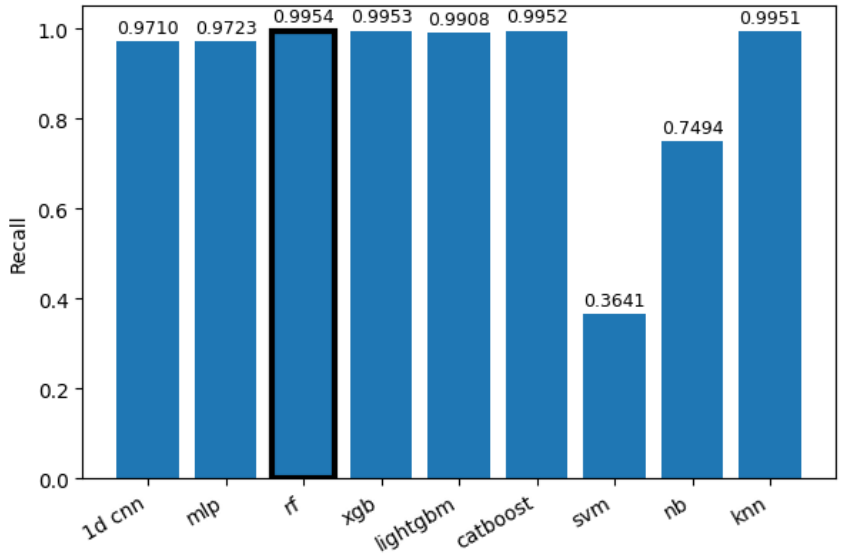
- Dataset: CIC-IDS2017[1]
- Offline:
  - ML models: Multilayer Perceptron (MLP), 1D Convolutional Neural Network (1D-CNN), Random Forest (RF), XGBoost (XGB), LightGBM (LGBM), CatBoost (CB), Support Vector Machine (SVM), Gaussian Naïve Bayes (GNB), and K-Nearest Neighbors (KNN).
  - Classification report: Global Accuracy, Precision, Recall and F1-score.
  - Feature importance.
- Online:
  - ML model: Random Forest.
  - Classification report: Global Accuracy, Precision, Recall and F1-score.
  - Latency of packet processing.
  - Throughput.

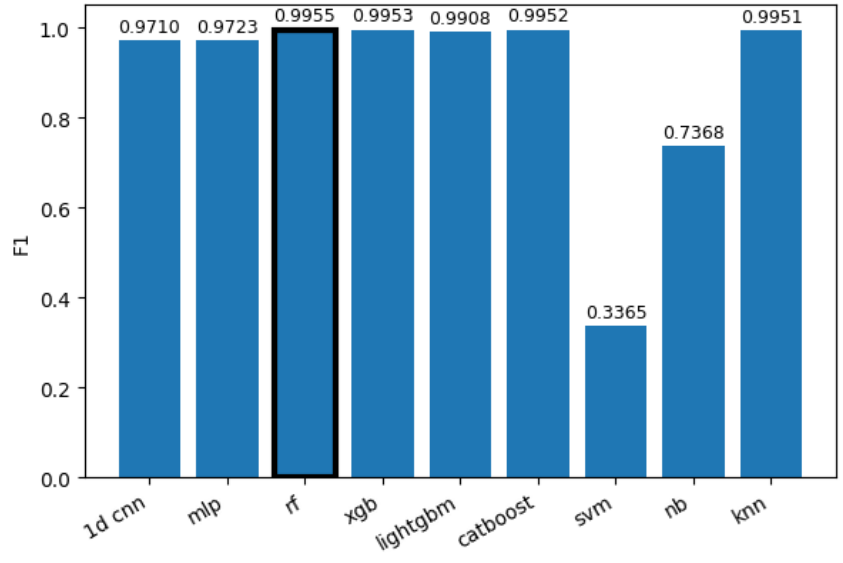
1. Sharafaldin, Iman, Arash Habibi Lashkari, and Ali A. Ghorbani. "Toward generating a new intrusion detection dataset and intrusion traffic characterization." ICISSp 1.2018 (2018): 108-116.

Offline Training Results

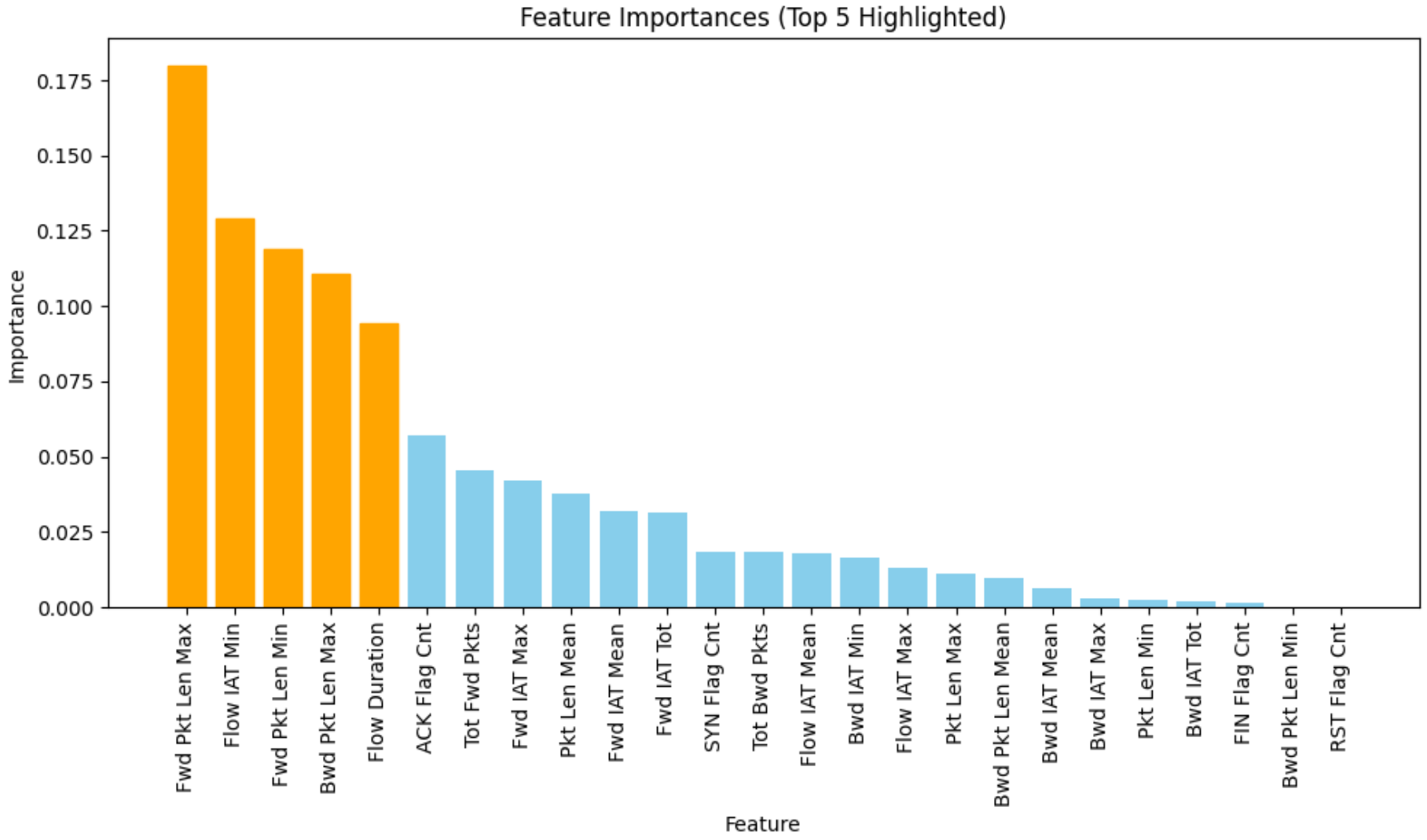






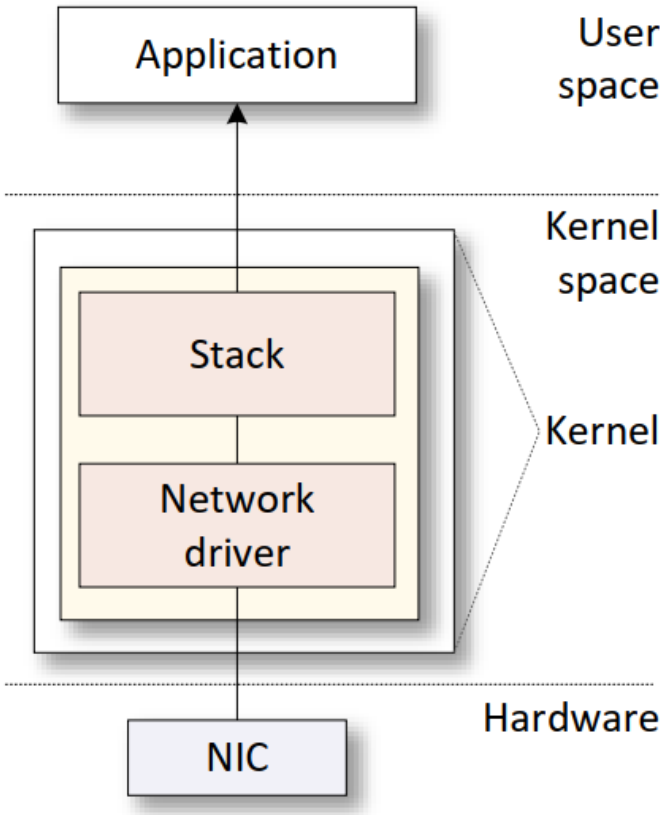


Offline Feature Importance



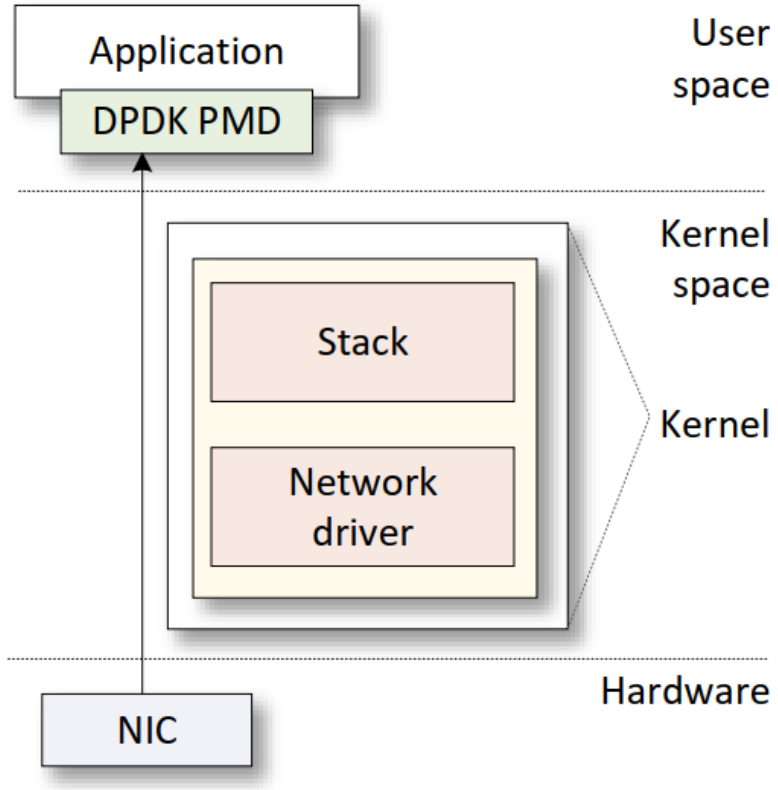
Standard Packet Processing

- The Network Interface Card (NIC) driver pre-allocates kernel memory buffers where the packets are stored.
- The NIC driver pre-allocate the transmit (TX) and receive (RX) ring buffer in the memory.
- The ring buffers store the packet buffer pointer and its length.
- The NIC copies the packet to the location using Direct Memory Access (DMA).
- The NIC triggers an interrupt.



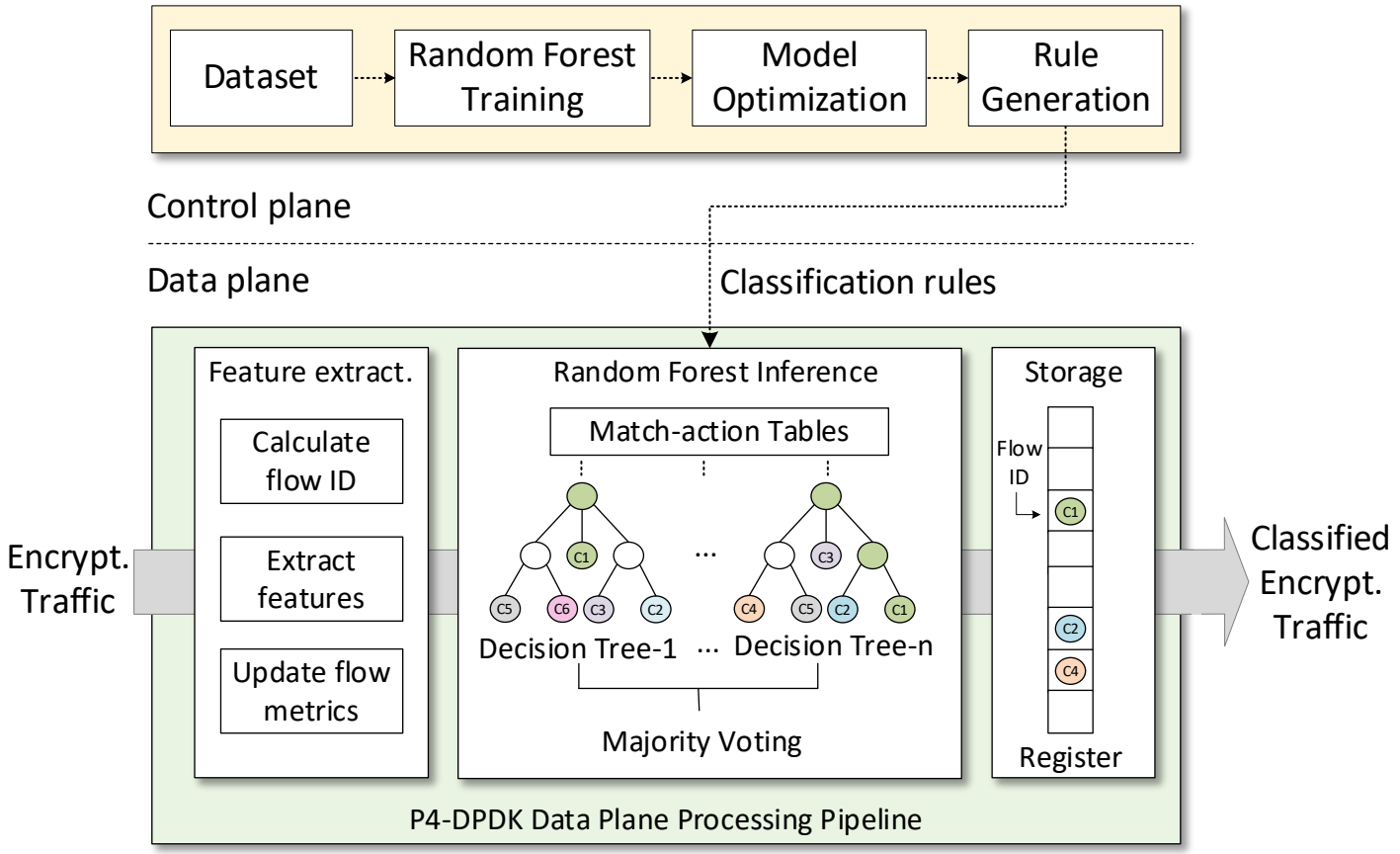
Kernel-Bypass Packet Processing Using DPDK

- Bypassing the kernel is a solution to avoid kernel overheads and accelerate packet processing.
- DPDK is a set of optimized libraries for processing packets in the user space while bypassing the kernel.
- DPDK uses Poll Mode Drivers (PMD) which constantly poll the NICs for new packets to avoid overheads resulting from interrupts.

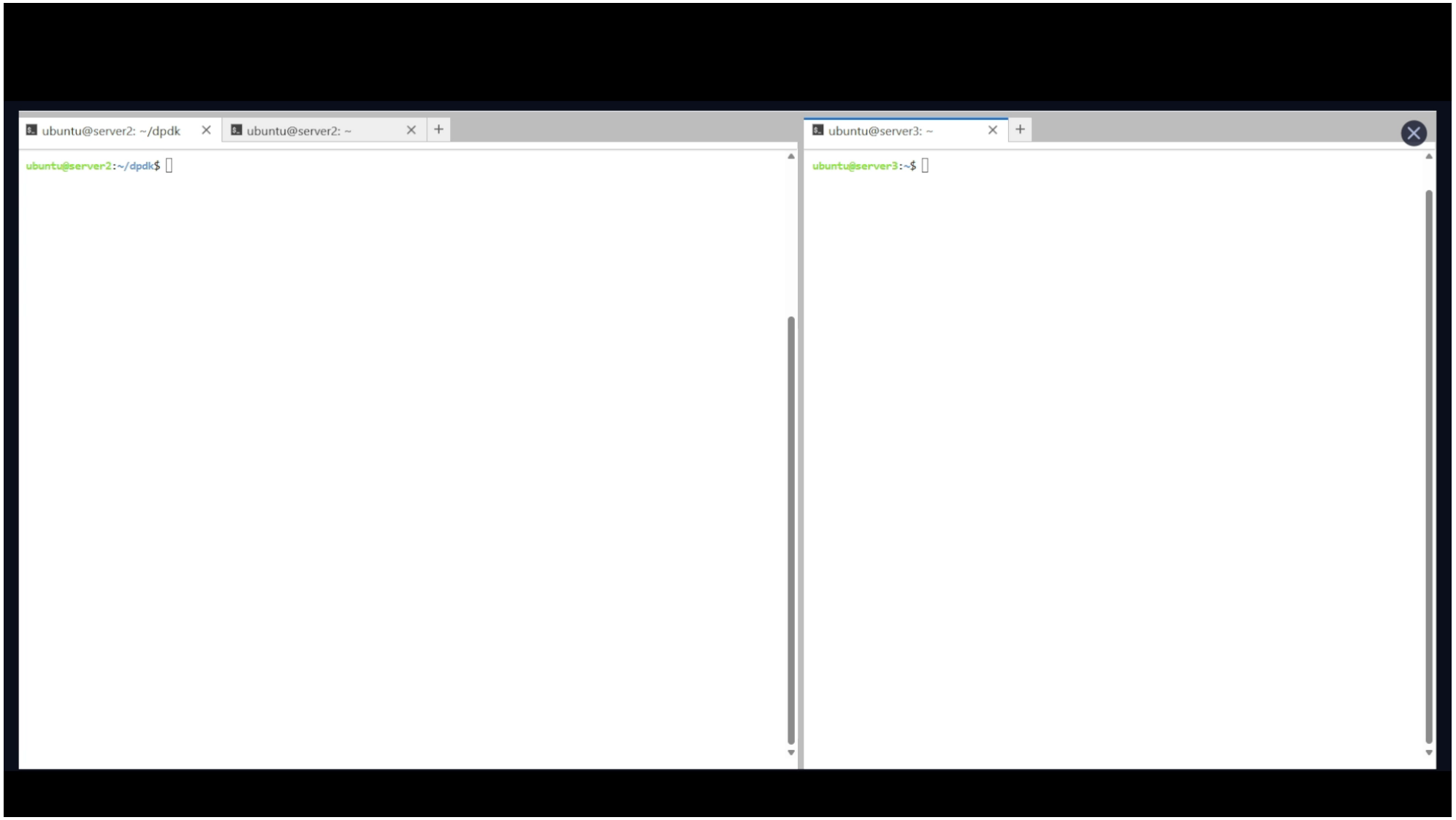


Proposed System

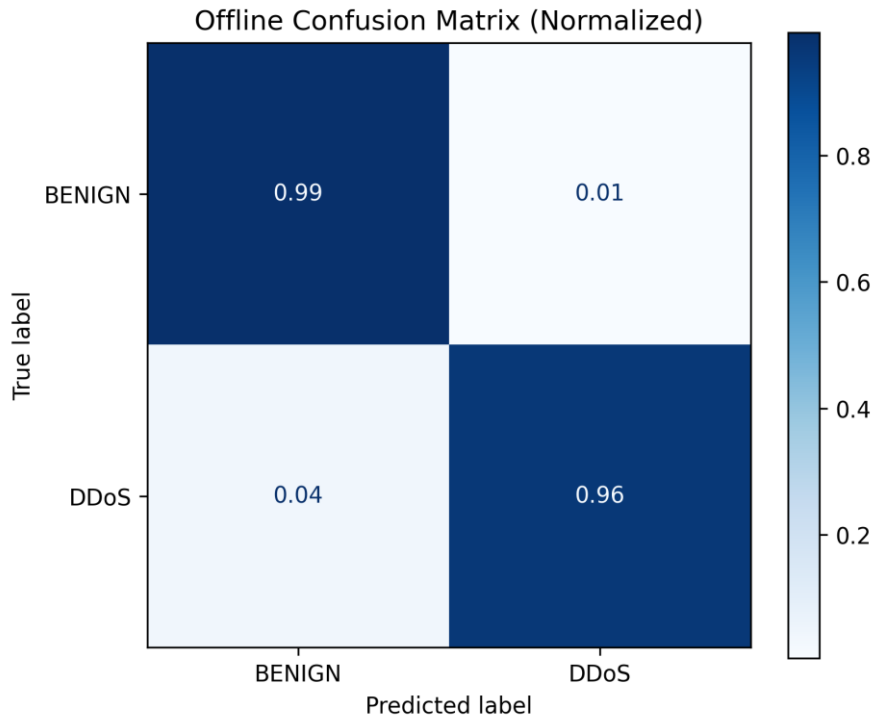
- The control plane is responsible of training the model offline.
- The system uses Random Forest to classify live traffic.
- The control plane, converts trained models into classification rules for deployment in the data plane.
- The data plane is responsible of extracting the features, implementing the trained model and storing the results.

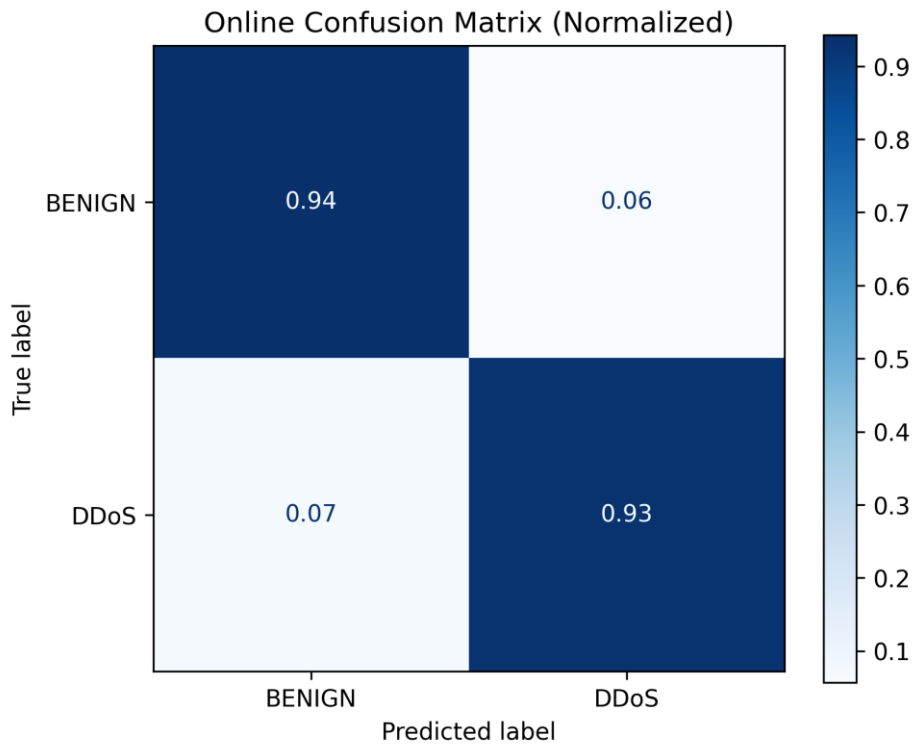


Demo


ubuntu@server2: ~/dpdk
ubuntu@server2: ~
ubuntu@server2:~/dpdk$
ubuntu@server3: ~
ubuntu@server3:~$

Training Results





Discussion and Future Work

- Limitations:
  - Depth of the tree is limited by the architecture of P4-DPDK
  - There is no division and multiplication, it means no complex features are feasible (e.g., Standard Deviation).
  - The system does not implement mitigation (e.g., drop or rate limit)
  - Evasion attacks are not considered during training

- Future work:
  - Train multiclass random forest
  - Add adversarial samples
  - Accelerate inference with parallel instructions (e.g., SIMD)
  - Extend to other datasets and cyberattacks

THANK YOU!